Field Deployable Hydrolysis System General Description

Summary

The Field Deployable Hydrolysis System (FDHS) is a modular chemical agent neutralization system, comprising a reactor and process skids (figure 1), as well as additional support equipment, that is capable of being deployed and set up in temporary locations to demilitarize a range of bulk liquid chemical agents and precursors. The system neutralizes chemical agents by heating and mixing with water and sodium hypochlorite, producing liquid effluent that while hazardous, does not pose the high level of lethality of the original agent. The FDHS will be able to hydrolyze/neutralize HD, VX, GB, EMPTA, Chloro-Amines, DF, and IPA. The process system includes the equipment and instrumentation required to operate and monitor the process, including a mobile laboratory facility, air supply, and carbon filtration system, and requires operational support to supply water, NaOCl, NaOH and movement of waste containers. Primary agent neutralization process equipment is maintained inside an environmental enclosure with carbon filtration. The system is designed to be capable of destroying hundreds of metric tons of target compounds during 24/7 operations. The system design anticipates an 80% Operational Availability. The FDHS maximizes use of redundant systems and interchangeable parts, standardized valves and interface fittings as much as possible, and allows for fast removal and replacement of components. It is designed to process bulk chemical warfare materiel (CWM) in containers and large bombs, and will not address explosives handling or destruction. The FDHS includes on-skid buffer storage that allows for continuous processing while accessing small items. Effluent storage capability is also included in the modular system through a combination of ISO containers and bladders. The system and Standard Operating Procedures (SOPs) allow operators to run the FDHS in a specific set of different prescribed modes. Examples include batch or continuous flow configurations, processing with or without static mixers or reactor agitation, and using multiple approved feed rates and agent/reagent ratios. Level B personal protective equipment (PPE) with liquid protection is assumed for standard operations.

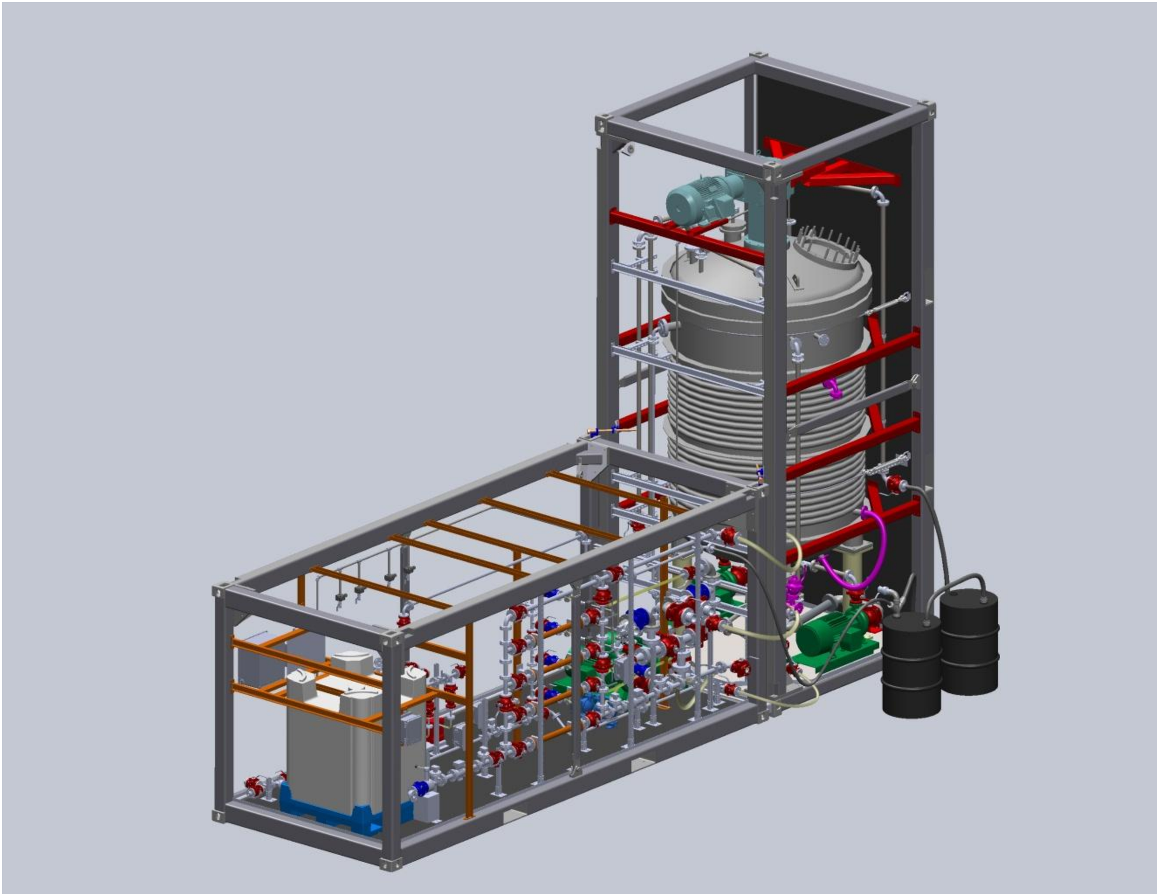


Figure 1. FDHS Reactor and Hydrolysis Skids

Transportability

The FDHS is designed as a self-supporting system that is easily transportable for rapid deployment and quick assembly. The primary process equipment (tanks, pumps, piping, reactor) are mounted on skids fitting in cube space of 8' x 8'6" x 20' for ease of shipment and setup. The skids are built inside International Organization for Standardization (ISO) frames that serve as standard shipping items. All other equipment will be packaged in standard 20' shipping containers. The modular system is configured for shipment in approximately 35 shipping containers. Upon arrival at target destination, the system and associated equipment will be set up on a 400' x 700' site (figure 2) with primary process established in an approximately 60' x 40' tented structure. Process support will include a trailer for the laboratory, skids for the generators and space for 3 each of active waste ISOtainers and/or bladders, which will reside outside the tent.

System Description

The FDHS is a transportable chemical process plant, capable of operating in a remote location, and without significant site infrastructure. The system provides its own generated power, air, processing equipment and lab facility to enable complete site operations. Consumables for process that are required to be supplied to support operations include water, sodium hypochlorite and sodium hydroxide. Some site preparation may be required as the platform requires a level, debris free space.

Figure 2 shows the proposed site layout for FDHS operations, identifying the process skids located in the environmental enclosure, generators, lab trailer, neutralent waste containers, supplied air generators and various support equipment placed outside the processing area on a site. The approximate footprint of the layout including the bladders is 400' x 700'

Primary systems making up the FDHS include:

- Water/Reagent supply
- Agent access and accumulation
- Neutralization Reaction process
- Neutralent waste accumulation
- Utilities/Support equipment
- Lab

The general FDHS process flow is shown below identifying the primary process steps around which the system was designed.

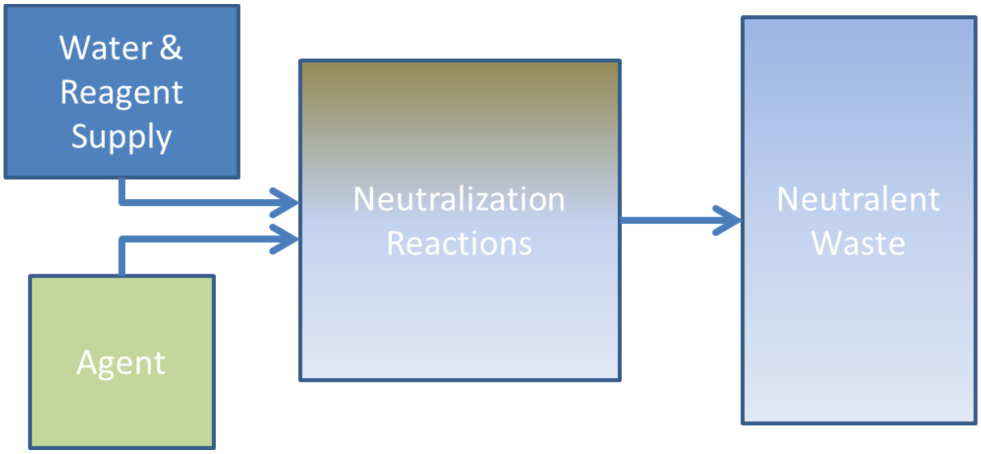


Figure 3 – FDHS process block flow diagram.

Key System Attributes

- Transportability: Skids containing the primary process equipment (tanks, pumps, piping, reactor) are 8'x20'x8.5' and are built inside ISO frames that serve as standard shipping items. All other equipment is packaged in standard 20' shipping containers.
- Availability and Maintainability: System maximizes use of redundant systems and interchangeable parts, standardized valves and interface fittings as much as possible, and allows for fast removal and replacement of system components.
- Process Flexibility: The system and SOPs allow operators to run the system in a specific set of different prescribed modes. Examples include batch or continuous flow configurations, processing with or without static mixers or reactor agitation, and using multiple approved feed rates and agent/reagent ratios. However, process chemistry may require higher ratios to be higher to enable single phase
- Safety and Environmental Consideration: System and support documentation is designed to be safely operated by military personnel or MNF assuming on-site oversight by process Subject Matter Experts. Level B PPE with liquid protection is assumed for standard operations. Primary agent neutralization process equipment is maintained inside an environmental enclosure with carbon filtration.
- Manual Process Control: All valves, pumps, generators, and compressors are operated manually. Instrumentation is limited to a small number of flow meters, temperature indicators, and pressure indicators with local and one remote read-out for process monitoring.

Assumptions and Limitations

The following items define further basis for the designed process, and identify areas where inputs to the process were assumed, as well as the boundaries for the capabilities of the system.

- The process design assumes limited duration of operations for the overall system. Although system is designed for continuous use, the total service life of 6 months was used for assessment of spares and materials selection.
- The design assumes that large quantities of water,12% sodium hypochlorite and 18% sodium hydroxide can be supplied to the site by others, at prescribed frequency to be defined after on-site assessment of agent “inventory”. (maintain 4,000 gallon tanks, where daily consumption can be as much as 5,000 gallons per day)
- The design assumes that diesel fuel can be delivered to the site by others (up to 1,000 gallons per day starting with first day on site).
- The site requires a 400’ x 700’ cleared space with a 100’ x 100’ area with zero grade, compacted surface near the center of the overall site for process equipment placement. Steel plates may be placed under equipment if needed and will be shipped with the process equipment skids.
- A 100-ton all-terrain crane and a 10,000-lb all-terrain forklift are required for setup. Shipping containers associated with the system may weigh up to 30,000 lbs, and a crane is required to upright the Reactor Skid.

Design Basis

Using the system requirements, neutralization chemistry and its associated drivers, such as mixing requirements, temperature requirements, length of operational service, and materials compatibility, the FDHS elements have established parameters they must meet for the system to function safely and efficiently. For each process area, the primary drivers for design of this system are identified as the basis for component inclusion, sizing and selection. Details of the specific components are defined under Equipment Description.

<u>Reaction Chemistry:</u> Neutralization of the expected agents and chemicals are well-established through significant experience by US Army programs demonstrating lab and full-scale neutralization processes. Selection of reagents and ratios of reagent to agent, feed rates to manage mixing and temperature, and compatibility of materials for high temperature and low pH environments all contribute to the design parameters established. The foundation of the design is to achieve the chemical reactions that have been identified to be effective for agent neutralization to target level of 99.9% destruction. Below in Table 1, are the throughput and reagent ratios for each agent.

Table 1. Designed Processing Rates and Reagent

CWM Compound	Throughput	Reagent	Reagent Ratio
HD	5 MT/day	Water	13.5:1
DF	25 MT/day	Water	5:1
Cl-Amines	16 MT/day	Bleach	10:1
EMPTA	24 MT/day	Bleach	8:1
IPA	Adulterate in containers	Water	1:1

Water/Reagent supply: The system requires inputs of large volumes (up to 1800 gallons per batch) of water and/or reagent depending on the chemical being processed. Additionally, for the HD and reaction, the water requires pre-heating to 190 F to maintain temperature before introduction of agent to the process. Reagent supply includes 12% NaOCl and 20% NaOH.

Agent access and accumulation: Because the form of agent containers is not defined and will not likely be known until system is on-site, the system must be capable of accumulating agent accessed by various means and from bulk and multiple smaller containers, to be able to provide consistent feed of agent to batch and continuous feed processes, like that proposed for DF.

Neutralization Reaction process: The range of agents and chemicals require neutralization capability in batch and in-line mixing. Significant agitation is required for HD/Water reaction and the VX/NaOH reaction to ensure effective agent destruction. DF/Water reaction occurs instantaneously, and does not require rigorous mixing, however, the exothermic nature of this process requires metered addition of agent to water to prevent boiling and steam generation. The Chloramine reactions can occur in agitated batch process, do not require heated reagent. Lab results show benefit to two-stage addition, to ensure continuous reaction process, and avoid temperature excursions. IPA/Water process does not require reactor, agitation, or temperature control, and therefore will not be processed through the system and will be handled in separate set-up that is designed to address flammability concerns with handling IPA.

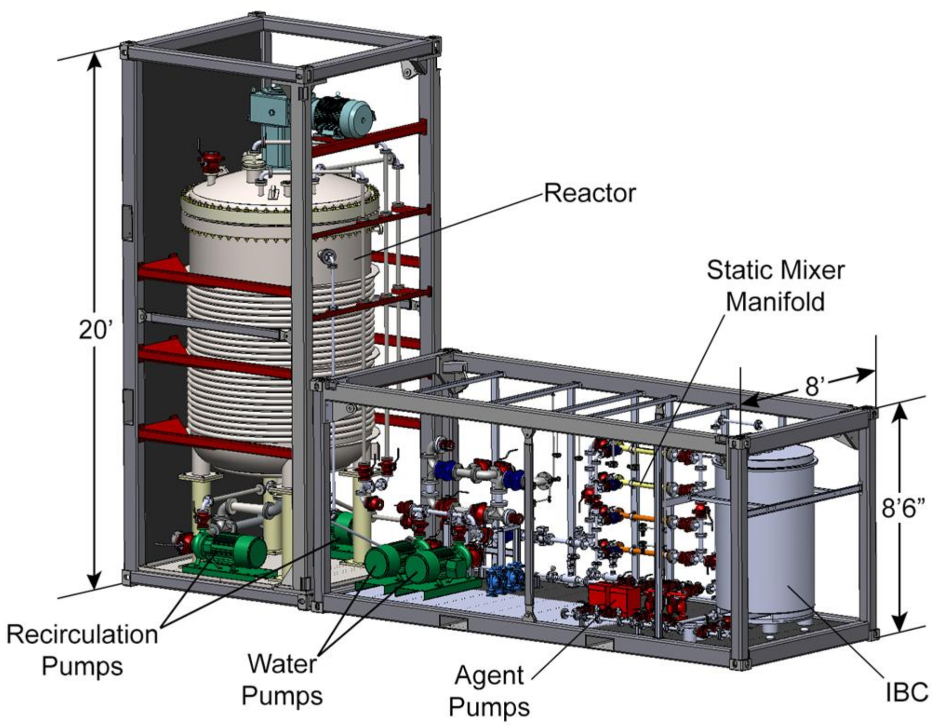
Instrumentation: The process must be equipped with appropriate instrumentation to monitor the process for temperature, pressure, pH, fluid flow and measurement of quantity of material processed.

Neutralent waste accumulation: Significant volumes of neutralent require collection at the end of the process. Neutralent from all reactions will be above ambient temperature, ranging from Chloroamines (140 F) to DF (~190 F). Additionally, neutralent waste will have low pH and will contain HCl, or HF, and therefore require containers to be specified to be compatible to adequately contain these materials. The proposed concept of using non-metallic containers for ultimate storage of neutralent requires capacity of neutralent accumulation to allow for cooling prior to transfer to the non-metallic containers, which typically are not suitable for fluids higher than 150 F.

Utilities/Support equipment: The FDHS process must supply power, air for instrumentation and personnel support, as well as lighting, and facilities for operations personnel to don/doff PPE and store tools and component spares. Power capacity needs to be sized to operate pumps, agitators, instrumentation, environmental control units, air supply, and others as defined in system equipment. Capability for decon of system needs to be integral to the system to enable flushing and changeover.
Lab: A self-contained onsite laboratory is required to enable analysis of process samples. At a minimum, the lab needs to be equipped to analyze samples to verify agents/chemicals that are inputs to the process, as well as waste neutralent samples to verify destruction.

System and Ancillary Equipment Description

- Primary Process Skid: This skid will be 8'x20'x8.5' and will house the static mixers and capability for bulk agent storage (~300 gallon capacity), and the majority of the process piping, pumps, and valves. Flexible hose connections will connect this skid to the adjacent Reactor Skid, and to the water and reagent supplies and waste tanks outside of the enclosure.
- Reactor Skid: This skid is 8'x20'x8.5' and houses a 2,200-gallon titanium reactor. This skid includes the High-Flow Reagent and Water Pumps and minimal piping and valves, and is connected to the Primary Process Skid with flexible hoses.



- Primary Water Tank: A 4,000 gallon tank which is part of the shipped system, but not residing inside the processing enclosure, will be connected to the process supply throughout operations. This tank will be supplied via flexible hose connections to water supplied by others. Water Tank Heaters: A recirculation heating system is connected to the Primary Water Tank, and is designed to keep that water at a temperature setpoint when heating is required per process chemistry. The use of the Primary Water Tank, and the maintenance of a fill level of greater than 50%, will allow operators to avoid the extended heating times that would be required to heat an entire container from ambient temperatures to the desired process feed temperature. To maintain reactor temperature during the HD neutralization operations, the water heating piping circuit will connect to the reactor jacket, allowing hot water to flow into the reactor jacket to enable pre-heating of the reactor upon start up of the reactions requiring heating.

- Environmental Enclosure: A General Purpose Outdoor Shelter (GPOS) with dimensions of 40'x58'x25' will be erected on site on the compacted, zero grade area. The Reactor Skid and Primary Process Skid will be located within the enclosure. To the greatest extent possible, accessing operations on the original agent storage containers will be performed inside the enclosure. The structure must accommodate the Reactor Skid, which will be 20' tall when placed in operational configuration. The structure will be erected after both Reactor and Process Skids are in place, so that it does not interfere with the use of MHE required for setup of these skids.
- Carbon Filtration System: A 5,600-cfm carbon filtration system will be connected to the Environmental Enclosure to remove and decontaminate agent vapors or VOCs within the enclosure. This filtration system is not intended to provide a target rate of air changes within the enclosure, or any minimum pressure differential. No near-real-time monitoring is planned within this enclosure, so operators will be in OSHA Level B PPE during operations.
- Generators: Three diesel-powered generators will be located outside the Environmental Enclosure, and will power all process equipment and ancillary equipment. These generators will be sized so that two generators can power all equipment on site including when water heating is required, with the third acting as a spare. One generator will be required to power all equipment when water heating is not required. The system's generators and air compressors have been sized and specified to power the process equipment, as well as all ancillary equipment referenced.
- Vapors from the agent buffer storage tank and Reactor will be captured from the top of these vessels and passed through a caustic vent drum scrubber to capture and neutralize agent. The vent drum scrubber will pass vapors through two wet chambers and a third "knock out" chamber before air is pushed to the system carbon filtration system.
- Electrical Distribution Panel: An electrical distribution panel will direct power to all powered equipment on site. One generator will be dedicated to the Water Tank Heaters. The other two generators will be set up to power the rest of the site equipment, with one of the two acting as a backup, configured with an automatic transfer switch. The backup generator will have the capability to be quickly rewired

to power the Water Tank Heaters in the event that the generator dedicated for that purpose fails.

- Air compressors: Two air compressors will provide compressed air to the air-driven pumps, instrumentation and air supply to the agent tank and reactor head space on the Primary Process Skid. One compressor at a time will be used, with the other one acting as a spare unit. These compressors will be located outside the Environmental Enclosure.
- Reagent Tanks: Reagent tanks will be located outside the Environmental Enclosure, and will supply NaOH or NaOCl to the system. The NaOCl supply must be greater than 1,800 gallons (per batch), so that enough reagent can be supplied to fill the reactor for batch reactions, and continuous supply of additional NaOCL may be required pending agent inventory at the site. NaOH must be provided in smaller quantities to be maintained at the site. These quantities will be delivered to the site by others.
- Neutralent Waste Tanks: The effluent lines from the process equipment will run to a common manifold located outside the Environmental Enclosure that will be used to connect to waste into one of five Neutralent waste tanks, each with a capacity of greater than 4,000 gallons. These will be connected via flexible hoses, filled manually, and after contents achieve desired minimum temperature (< 150 F), they will be connected to discharge contents to field containers for final neutralent storage. Neutralent waste tanks will be specified to accommodate extreme pH (hydrofluoric and hydrochloric acids) and temperatures up to 200°F. A second Vent Drum Scrubber unit identical to the one connected to the Reactor and Agent Buffer Storage tanks, will be connected to vent lines capturing waste tank vapors. This waste vent drum scrubber system will also connect to the system carbon filtration system to ensure capture of agent and other harmful vapors coming from the neutralent in the waste tanks while it cools.
- Neutralent Bladders: Flexible containers in 20,000 gallon capacity will be placed on-site removed sufficiently from the process so as to not interfere with movement on the process site, to hold the final neutralent solutions. The bladders will be filled from waste tanks via flexible hose connections and neutralent pump placed between initial hose connection and bladder hose connection. Neutralent will maintain reaction chemistry segregation in the field. Once filled, bladders will be fixed on the site for indefinite storage.
- Mobile Laboratory Expandable Shelters: One expandable shelter will be located on site away from the primary processing Environmental Enclosure, and will house all laboratory equipment. These shelters ship in an 8'x20'x8' configuration, and are 24'x20'x8' when set up on site. The FDHS set up procedures will address setting the laboratory up and connecting power supply from generators.
- Personnel Decontamination Station (PDS) Enclosure: The PDS Enclosure will be connected to the entrance of the Environmental Enclosure, and will provide an area

for decontamination of personnel leaving the operational area. The enclosure will be roughly 15’x20’.

- Breathing Air Compressor and Cascade System: A combined breathing air compressor and cascade platform will be located outside the Environmental Enclosure, and will provide supplied air to personnel in the operational area. Approximately six supplied air lines will be provided in the Environmental Enclosure or PDS Enclosure.

Process Equipment Design Parameters

The system is designed to be operated in batch configuration using a reactor for mixing or continuous flow configuration allowing for mixing in-line using static mixers:

- Batch Configuration: The Reactor Skid houses a 2,200-gallon titanium reactor, which is equipped with an internal agitation system. The system is designed to incorporate this reactor into several different batch processing options. Agent, water, and reagent can all be pumped directly to the reactor. A set of high-flow pumps allows operators to set valve configurations to draw material from the reactor to either recirculate back to the reactor for extended mixing and reaction times, or drain directly to Neutralent waste tank. This recirculation loop can also pass through static mixers, which are configured to allow for in-stream injection point for agent. The batch configuration can be operated with or without agitation, recirculation, or static mixers, as each agent neutralization “recipe” requires.
- Continuous Flow Configuration: The continuous flow configuration does not use the titanium reactor. This configuration supplies water or reagent to the inlet of the static mixers and supplies agent to the static mixer injection ports. Upon exiting the static mixers, the mixture flows directly to the Neutralent waste tanks.

Operations Personnel

The system is expected to run 24 hours per day, 7 days per week. Three shifts are required to support this schedule, with up to 15 personnel per shift. Three of the 15 people per shift are expected to by civilian SME. Other personnel on site may be active-duty military or foreign nationals. Required personnel specialties include chemical plant operators, PDS operators, maintenance technicians, and chemists.

Civilian SME from ECBC will be involved in the fabrication, systemization, and documentation preparation phases of the FDHS project. During systemization, these personnel will assist in the validation of SOPs. The systemization and SOP validation activities will serve as training for these personnel. After the 1 July completion date, additional training materials may be prepared as part of a Program of Record, with the aim of eventually training active-duty military personnel after Material Release of the system.